Design Activity Worksheets for Developing Research Questions

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Abstract

Developing good research questions is a skill that develops over time and is often difficult for students. More often than not, it is up to the student to determine what to research. Where do I start? What do I look for? Is this a good research question? These are just a few of the questions students ask and should ask in the early stages of their research process. This work describes a progressive plan for developing research questions using a series of four design activity worksheets to guide students through the cognitive and metacognitive processes of choosing topics, asking questions, identifying an appropriate problem and locating adequate data sources. The worksheets are introduced in a linear manner and completed in order. This progressive path is intended to provide a logical and methodical approach for developing research questions. However, each worksheet can be completed independently. The worksheets can also be used as a pedagogical approach to introduce research methods into the classroom. The design activity worksheets have been used in multiple venues: undergraduate and graduate data visualization courses, workshops and more recently, a graduate seminar designed to help students identify their thesis topics in partial fulfillment of their graduate degree. In this work, we describe the development and characteristics of the worksheets and report some preliminary results of a study designed to assess their perceived impact and usefulness from a student's perspective.

Introduction

The abundance of literature on developing research questions ([1] – [3], to name a few) concur: there are grand ideas, good ideas, and doable ideas. In the case of executing a research project, being able to recognize these differences is essential to moving the project from planning to data collection to analysis, and finally, to implementation [4]. However, developing research questions is a skill that many graduate students lack. Most graduate students do not have extensive experience in research methodology [4] and struggle with identifying a problem then developing a reasonable approach to solving the problem.

This paper presents an approach that uses worksheets to guide students through the process of identifying topics, transforming topics into questions, using those questions to create an effective problem statement and identifying viable data sources. This process engages students in a critical assessment of their ideas and the research questions they pose. The purpose of this work is to examine students' perceptions and attitudes toward the use of these worksheets. To validate our strategy, the design activity worksheet approach was implemented in a graduate level research seminar course at Purdue University in West Lafayette, Indiana, in Fall 2019.

Design Activity Worksheets

To help new investigators, specifically graduate students new to research, understand the process of generating good research questions, a series of worksheets were developed. The worksheets were inspired by the well-established work of [5] who provide detailed content on each of the topics covered. The worksheet workflow is shown in Figure 1.

Figure 1 Design Activity Worksheet Workflow.

The goal of the first worksheet in the series, *"Identifying Topics,"* is to identify and rank a minimum of three topics of interest. The *w*orksheet consists of five questions designed to motivate students to consider their surroundings and things that are of interest to them: 1) List three topics that interests you, 2) Which topic interest you the most? 3) What do you know about each topic? 4) What do you not know about each topic? and 5) Compare and rank the topics.

We anticipate that students who choose a topic that they feel connected to are motivated to take the steps necessary to complete the research process. At this point, topics are generally either too broad or too narrow. It is unknown which or if any of the topics will be fully developed into a robust research question. In the event students reach an impasse in their efforts and decide to consider other options, the list of topics generated in this stage can be utilized to minimize time identifying a new topic. Upon completion of this worksheet students will generate, compare and rank topics of interest and identify who the intended audience is for their work.

The goal of the second worksheet, *"From Topics to Questions,"* is to generate questions based on the main topic of interest identified in the previous worksheet so students can transition from a broad topic to a specific question. Upon completing this worksheet, students will articulate what they hope their target audience will understand after reading their work. The worksheet consists of three questions: 1) state the topic they are interested in studying in a complete sentence, 2) answer a series of vital questions, they should know about their topic: essentially motivating them to think critically about the significance of their topic, and 3) state, in a complete sentence, what they hope their research will help the reader to understand. The goal is to guide the student from being a mere data collector, to a researcher interested in understanding their chosen topic better.

The goal of the third worksheet, *"From Questions to a Problem,"* is to transition from a specific question to developing a problem statement. Upon completing this worksheet, students will identify the situation or condition they desire to address, the consequences caused by that condition and why it is important to address the problem. Students are encouraged to refer to their answers to the previous worksheets as they complete the third worksheet. To ensure continuity, the first part of the worksheet focuses on helping students articulate their topic, state the question they will address and why the work is important. Students are asked to summarize this information succinctly in one sentence, as suggested by [5]. The completed sentence should read "The topic I am studying is *X*, because I want to find out *Y*, in order to help my reader understand *Z*." where *X* is the topic of study, *Y* is the question that needs to be answered, and *Z* is the significance of the work.

In addition, this worksheet is also designed to help students to determine if the problem they plan to address is a practical or conceptual problem [5], [6], by answering the following questions:

a. Practical Problem: What do you want your reader to do after reviewing your work?

b. Conceptual Problem: What should the reader think after reviewing your work?

Once the topic has been identified, the question posed and the problem stated, the next step is to identify appropriate data sources using the final worksheet, *"From a Problem to Data Sources."* The process of going from a problem statement to data sources within the construct hypothesis testing involves forming and testing a hypothesis and determining the right data and data sources to accomplish the task. The worksheet consists of four questions. The first question asks students to describe their semester topic again, using the sentence structure adapted from [5] followed by a statement, specifically for the new graduate researcher, to help them begin to think about the next step: I need data to support and test my research question.

The second question focuses on different types of data. The varied backgrounds and experiences of the students mean their disciplinary perspectives are different and will be reflected in the types of data they will work with in their research practices [4]. Students have a general understanding of what data is but may not be aware of the different types of data sources (i.e., primary, secondary and tertiary). The worksheet provides a short description of the types of data sources to facilitate recall of the in-class lectures and discussions on the topic. Students are asked to identify a minimum of three data sources, and a variety of sources (where applicable).

The third question addresses the challenge of identifying *appropriate* data sources to motivate students to start thinking critically about the data they have identified. Students are also asked to evaluate their data sources for relevance and reliability.

The last question asks students: *"If the data does not exist yet, describe the data (variables, information) you will need for your research."* This might be a difficult question, especially for students who have not selected a research topic. The purpose is to facilitate cognitive thought towards what their research data might look like and what data they will need to ultimately address a research question and provide a solution to the problem.

The worksheets are intended to be a cumulative exercise where content from previous worksheets inform the content of the current worksheet. Each worksheet forces students to think more deeply about their topic and the problem they hope to address. This could lead to changes in topics, questions and problem statements.

Methodology

To determine whether the proposed approach and design worksheets help students develop sound research questions, the worksheets were assigned to three graduate student cohorts (first, second, and third semester, mostly master's degree students) as part of a graduate seminar at the university over a four-week period that paralleled lecture content. A total of 55 students enrolled in the 1-credit graduate seminar in Fall 2019: 1st semester (20), 2nd-semester (9) and 3rd-semester (26) participated in our study. The worksheets and their corresponding assessment were given as homework assignments at the end of each class period (50 minutes, weekly).

The seminar is designed to assist new students as they begin their endeavors in graduate school, introduce each aspect of the research process, including literature review, data collection and

writing, and facilitate the identification of areas of interest and the development of their thesis by providing support from other students and faculty. The seminar is implemented as a forum for discussing ideas, research questions, and presenting proposals.

The worksheets were used to reinforce classroom discussions and help students to think about their research. Students were asked to complete and submit a worksheet weekly for review by the course instructor. After submitting each worksheet, students were asked to complete a survey designed to assess effectiveness and students' perceptions of the worksheet and provide an opportunity to give feedback. The survey captured the following demographic information: term the course taken, students' research focus (e.g., animation, visualization, user experience, etc.), students' cohort (1st, 2nd, or 3rd semester), preferred pronouns (he/him/his, she/her/hers) and graduate program (master's or PhD).

A 5-point Likert scale (1-Strongly disagree, 2- Disagree, 3- Neutral, 4- Agree, 5- Strongly Agree) was used to allow students to indicate the level of agreement/disagreement to statements reflective of the goals and objectives of each worksheet. To better inform iterative refinement of the worksheets for future use, if students disagreed or strongly disagreed with a statement, they were asked to provide a brief explanation. The last question for each worksheet asked students to indicate, on average, the amount of time was spent on completing each worksheet (0-30 minutes, 30 minutes to one hour, 1.5 hours – 2 hours, and 2.5 hours or more). For each assessment survey, all Likert scale questions are followed by an open-ended question to allow the student to provide qualitative feedback if they strongly disagreed or disagreed with a statement.

Results

This section summarizes the feedback results from our study. The results are presented inclusively from the perspective of the entire class. Analysis of demographic data showed that 63% of respondents self-identified using the pronouns he/him/his, 35% as she/her/hers and 2% preferred not to answer. The research foci of the class were representative of the variety of research paths available to graduate students enrolled in the Computer Graphics Technology Graduate Program which included: animation (8%), data visualization (14%), FX (29%), gaming (12%), non-thesis (2%), Product Life Management (2%), Robotics (4%), User Experience (20%). Eight percent (8%) did not provide a research focus. All research foci that contained the word virtual reality (VR), augmented reality (AR) or graphics were grouped together as FX. All research foci referring to information and visualization are grouped as data visualization. Students are asked to provide this data on each feedback survey. The demographic data is reported from the first completed survey *"Identifying Topics,"* with the assumption that students' research focus/interest remained the same over the time span for which feedback was provided. Statistical indicators (mean, median, mode, standard deviation and variance) are calculated for each worksheet, and for each question of each worksheet.

Worksheet 1: Identifying Topics

A total of 49 student provided feedback on the "*Identifying Topics Worksheet."* Nineteen responses were from the first-semester cohort, seven responses were from the second-semester cohort and twenty-three responses were from the third-semester cohort. Likert data for the class,

organized by question, calculated from student responses to the *"Identifying Topics"* feedback survey is shown in Table 1.

The mean for each question ranged from 3.5 to 3.8, indicating neutral responses. Standard deviation for question 1 suggests responses were similar across level of agreement options. Questions 2 and 3 had identical values of 3.5, 4, and 4 for mean, median and mode, respectively. However, the standard deviation for question two is slightly smaller suggesting respondents were neutral/boarder line in agreement that the worksheet helped in understanding the relevance of the task of choosing a research topic. The larger standard deviation calculated for question 3 suggests responses to question three were more spread out across respondents regarding having a clear idea of topics before completing the worksheet.

Table 1. Statistical indicators, by question, from student responses to the *"Identifying Topics"* feedback survey *(n=49)*.

Question	Mean	Median	Mode	Std_Dev
Q1. I found the *Topics Worksheet* to be helpful in generating topic ideas.	3.387	3	3	0.965
Q2. The worksheet helped me to understand the relevance of the task of choosing a topic.	3.571	4	4	0.857
Q3. I had a clear idea of topics before completing the topics worksheet.	3.571	4	4	1.049

Student responses for each of the three questions are shown in Table 2. As the responses show, 41% of respondents found the worksheet to be neutral in helping to generate topics ideas, 53% agreed the worksheets helped to understand the relevance of the task of choosing a topic, and 37% agreed, they had a clear idea of topics before completing the worksheet. Less than half the respondents disagreed.

Table 2. Student responses, percentage of responses (count).

Question (Respondents = 49)	(1) Strongly Disagree	(2) Disagree	(3) Neutral	(4) Agree	(5) Strongly Agree
Q1. I found the *Topics Worksheet* to be helpful in generating topic ideas.	6% (3)	6% (3)	41% (20)	37% (18)	10% (5)
Q2. The worksheet helped me to understand the relevance of the task of choosing a topic.	4% (2)	4% (2)	31% (15)	53% (26)	8% (4)
Q3. I had a clear idea of topics before completing the topics worksheet.	2% (1)	16% (8)	24% (12)	37% (18)	20% (10)

Worksheet 2: From Topics to Questions

A total of 46 students provided feedback on the "*Topics to Questions*" worksheet. Fifteen responses were from the first-semester cohort, seven responses were from the second-semester cohort and twenty-four were from the third semester cohort. Statistical indicators for results from the *"Topics to Questions"* feedback survey, by question, are shown in Table 3. The mean value for both questions is four, indicating that on average, students agreed the worksheet helped to

identify the significance of the topic identified by helping to articulate what students want to learn about the topic and what students want to help their readers understand about the topic. Although the most frequent response was four (agree), students' responses varied across levels of agreement, as indicate by the standard deviation for each question

The results in Table 4 support the statistical indicators. Responses to question 1 show 63% of the responses were positive (52% agree, 11% strongly agree), 9% strongly disagreed, 7% disagreed and 22% were neutral. Regarding students' perception of the worksheet helping to identify the significance of the topic to articulate what they want to help the reader understand about the topic, 58% of the responses were positive (41% agreed, 17% strongly agreed), 30% were neutral, 4% disagreed, and 7% strongly disagreed.

Table 3. Statistical indicators from student responses to the *"Topics to Questions"* feedback survey *(n=46)*.

Question	Mean	Median	Mode	Std_Dev
Q1. The worksheet helped me to identify the significance of my topic by helping me to articulate what I want to find out about the topic.	3.5	4	4	1.058
Q2. The worksheet helped me to identify the significance of the topic by helping me to articulate what I want to help my reader understand.	3.586	4	4	1.0336

Table 4. Student responses, percentage of responses (count).

Question (Respondents = 46)	(1) Strongly Disagree	(2) Disagree	(3) Neutral	(4) Agree	(5) Strongly Agree
Q1. The worksheet helped me to identify the significance of my topic by helping me to articulate what I want to find out about the topic.	9% (4)	7% (3)	22% (10)	52% (24)	11% (5)
Q2. The worksheet helped me to identify the significance of the topic by helping me to articulate what I want to help my reader understand.	7% (3)	4% (2)	30% (14)	41% (19)	17% (8)

Worksheet 3: From Questions to a Problem

A total of 43 students provided feedback on the "From Questions to a Problem" worksheet. Seventeen responses were from the first-semester cohort, eight responses were from the second-semester cohort, and eighteen responses were from the third-semester cohort. Statistical indicators, by question, are shown in Table 5.

Table 5. Statistical indicators from student responses to the *"From Questions to a Problem"* feedback survey *(n=43)*.

Question	Mean	Median	Mode	Std_Dev

Q1. The worksheet helped to identify the topic as a practical or conceptual problem.	3.647	4	4	1.025
Q2. The worksheet helped me to understand what I want the reader to DO after viewing the project deliverables.	3.395	4	4	1.164
Q3. The worksheet helped me to understand what I want the reader to THINK after viewing the project deliverables.	3.488	4	4	1.168

The mean for all three questions ranged from 3.3 to 3.6, indicating neutral responses to the feedback survey; however, the *mode for each question is 4, indicating* most frequent response w*as* "Agree." *The standard deviation for each question suggests r*esponses were varied across levels of agreement options for each question. Table 6 shows responses to questions 1-3 were mostly positive.

Table 6. Student responses, percentage of responses (count).

Question (Respondents = 43)	(1) Strongly Disagree	(2) Disagree	(3) Neutral	(4) Agree	(5) Strongly Agree
Q1. The worksheet helped to identify the topic as a practical or conceptual problem.	9% (4)	7% (3)	30% (13)	37% (16)	16% (7)
Q2. The worksheet helped me to understand what I want the reader to DO after viewing the project deliverables.	12% (5)	7% (3)	26% (11)	42% (18)	14% (6)
Q3. The worksheet helped me to understand what I want the reader to THINK after viewing the project deliverables.	9% (4)	9% (4)	23% (10)	40% (17)	19% (8)

Worksheet 4: From a Problem to Data Sources

A total of 25 students provided feedback on the "*Problem to Data Sources*" worksheet: 8 (32%), 5 (20%) and 12 (48%), in each cohort, 1st-semester, 2nd- semester, and 3rd- semester, respectively. Table 7 shows the statistical indictors calculated from student responses to the "From a Problem to Data Sources" feedback survey.

Table 7. Statistical indicators from student responses to the four questions from the *"From a Problem to Data Sources"* feedback survey *(n=25)*.

Question	Mean	Median	Mode	Std_Dev
Q1. The worksheet helped me to identify primary data sources for the project topic.	3.12	3	3	1.142
Q2. The worksheet helped me to identify secondary data sources for the project topic.	3.28	4	4	1.183
Q3. The worksheet helped me to identify tertiary data sources for the project topic.	3.16	3	4	1.189

Q4. The worksheet helped to assess if I had enough data sources and data for the project topic.	3.36	4	4	1.195

Of the four questions, question 4 has the largest mean value of 3.36, indicating that, on average, the class was neutral in its perception of the worksheet to help in identifying data sources. The mode value for questions 2, 3 and 4 is 4, indicating the most frequent response was "agree." The most frequent response for question 1 was "neutral." The responses for all questions varied across the level of agreement options. Table 8 summarizes students' responses to the four questions. The data shows responses to all questions were mostly positive.

Table 8. Student responses, percentage of responses (count).

Question (Respondents = 25)	(1) Strongly Disagree	(2) Disagree	(3) Neutral	(4) Agree	(5) Strongly Agree
Q1. The worksheet helped me to identify primary data sources for the project topic.	16% (4)	4% (1)	40% (10)	32% (8)	8% (2)
Q2. The worksheet helped me to identify secondary data sources for the project topic.	16% (4)	4% (1)	24% (6)	48% (12)	8% (2)
Q3. The worksheet helped me to identify tertiary data sources for the project topic.	16% (4)	8% (2)	28% (7)	40% (10)	8% (2)
Q4. The worksheet helped to assess if I had enough data sources and data for the project topic.	16% (4)	0% (0)	28% (7)	44% (11)	12% (3)

Time to Complete Worksheets

The following scale was used to quantify the time options respondents were given to indicate the amount of time spent on each worksheet: 1- 0-30 minutes, 2 - 30 minutes to one hour, 3- 1.5 hours – 2 hours, and 4- 2.5 hours or more. Smaller mean values indicate less time taken to complete a worksheet. Table 9 shows the statistical indicators calculated for the time to complete for each worksheet.

Table 9. Statistical indicators calculated for time to complete each worksheet.

Worksheet	*n*	Mean	Median	Mode	Std. Dev
Identifying Topics (Q4)	49	1.938	2	2	0.766
From Topics to Questions (Q3)	46	1.913	2	2	0.904
From Questions to a Problem (Q4)	43	1.837	2	2	0.860
From a Problem to Data Sources (Q5)	25	1.720	2	1	0.825

Discussion

A total of 6 responses of strongly disagree, and 13 responses of disagree were reported in response to three statements on the "Identifying Topics" worksheet. Among the 19 responses, 6 respondents did not provide feedback to explain their response. For the remaining 13 responses

comments varied; however, recurring comments included: “I already have a topic chosen and I am well into the writing of my proposal,” “Non-thesis Track,” “I think a discussion with my advisor will be more helpful,” “This is something I have been struggling with in general,” and “the thinking points are already fairly obvious.” Students were not asked to provide comments if they responded strongly agree or were neutral; however, the following comments were provided: “Helped me narrow down the major areas I would like to focus on for the thesis project,” and I did not have a clear idea before completing the topics worksheet and this worksheet helped me think about it,” as comments to “Strongly Agree” and “Neutral” responses, respectively.

A total of 7 responses of “Strongly Disagree,” and 5 responses of “Disagree” were reported in response to students’ perception of the *“Topics to Questions”* worksheet. Six of the 12 responses were not accompanied by feedback. The remaining responses included similar comments as noted above, but also included, “I have already written my proposal and discussed my topic in depth with my advisor, so the significance of my topic has already been established,” “I still don't consider my topic to be terribly significant in any kind of pressing academic sense. It's interesting at best, and very interesting to me specifically. That is all,” and “Not useful at all. I'm still not sure what exactly topic I want to choose so I can only put something in the form.” This last statement is a bit concerning considering this comment was made by a member of the third-semester cohort. The following “neutral” comments were also provided “How should we define the significance of a topic?”

A total of 13 responses of “Strongly Disagree,” and 10 responses of “Disagree” were reported in response to students’ perception of the *“From Questions to a Problem”* worksheet. There were no comments provided for 17 of the responses. The remaining 6 responses, that differed from the previous comments, included, “I'm still not sure what my reader should do” and “I'm still not sure what my reader should think. An example might help.”

A total of 16 responses of “Strongly Disagree,” and four responses of “Disagree” were reported in response students’ perception of the “Problem to Data Sources” worksheet. No comments were provided for half of the responses. The remaining 10 responses, that differed from previous comments included, “It would be nice to have some sort of reference on whether to find synthesis data because most scholar sites don't have that readily available,” and “Already had my sources.”

As shown in Table 9, the largest number responses were received from the first worksheet, from all cohorts; however, participant numbers gradually declined for all cohorts with each feedback survey with a dramatic decrease in feedback for the last worksheet. Overall students’ perception of the series of worksheets in helping to develop research questions was positive. The mean for all worksheets hovered around a value of 3, but was very close to 4, indicating a positive perception of the series of worksheets to help students gain experience developing research questions. Table 9 shows, on average, students took 30 minutes to an hour to complete each worksheet.

Although we perceive the outcomes of this work to be positive, we acknowledge the following limitations. More work is needed in guiding students through the process of thinking through

ideas for topics, specifically for first- and second-semester students. Several students indicated their topics and questions had already been determined and did not find the worksheets useful. Future versions of the worksheets will take into account other possible states students could be in their research and provide questions that will allow them to elaborate on their research status. It would also be interesting to examine, among students who report having an existing research topic, whether the topic was researched and selected by the student or identified by the student's advisor. One student commented, "This worksheet was really angled towards quantitative studies, and did not leave room for qualitative research methods." The authors will work to make future versions of the worksheets amenable to both quantitative and qualitative research methods. We also acknowledge the word "Research" has different implications in different disciplines. The worksheets are designed to be assist with the selection and filtering of ideas. Future implementations of the worksheet method will give students the option to seek feedback from their research mentors as they complete the worksheets. Finally, we are preparing a comparative study among different cohorts to evaluate the perceived value of the worksheets over time and determine at what point they are most effective.

Conclusion

The design activity worksheets were introduced and implemented in a graduate level research seminar to guide students through the process of identifying research topics, identifying a problem to be addressed by their work and clearly stating their research question. At a minimum, the worksheet method motivates students to think critically about their topics, the questions they need to ask, and the data needed to support their research. Although the focus of the results reported in this work has been primarily on students' perception, the worksheets can be used to complement pedagogy of research methods as well as points of reference as students rotate out of the graduate course and transition into their research roles.

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